Functional Requirement Specification

Project X and PXIE Radio Frequency Quadrupole

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Revision History

Revision	Date	Section No.	Revision Description
0	1/4/2012	All	Initial Release.
1	7/9/2012	0,2,4	Changed Project Engineer. Removed no beam vacuum specification and adjusted alpha parameters specification. Removed statement about limit to average current in downstream linac.
2	10/3/2012	4	Changed description of 50 C nominal temperature and added nominal cooling water temperature requirement.
3	2/8/2013	0-3	Changed signature authority. Exanded scope to include RF power, vacuum, and cooling. Removed high vacuum interface and reliability requirement. Added explicit list of system interfaces.
4	2/11/2013	4	Increased overall width from 1.4m to 1.6m.

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1. Introduction:

Project X is a high intensity proton facility conceived to support a world-leading physics program at Fermilab.[1] Project X will provide high intensity beams for neutrino, kaon, muon, and nuclei based experiments and for studies supporting energy applications. The Project X Injector Experiment (PXIE) will be a prototype Front End linear accelerator,[2] that will validate the concept for the Project X front end, thereby minimizing a large portion of the technical risk within Project X.

The overall layout of the PXIE components is shown in Figure 1. The PXIE Radio Frequency Quadrupole (RFQ) accepts the beam at 30 keV as it exits the LEBT[3] and accelerates it to 2.1MeV where it is transferred to the Medium Energy Beam Transport (MEBT) section.[4] This specification includes the beam physics, physical size limitations, RF requirements, alignment, vacuum, and cooling requirements and is applicable for both Project X and PXIE.

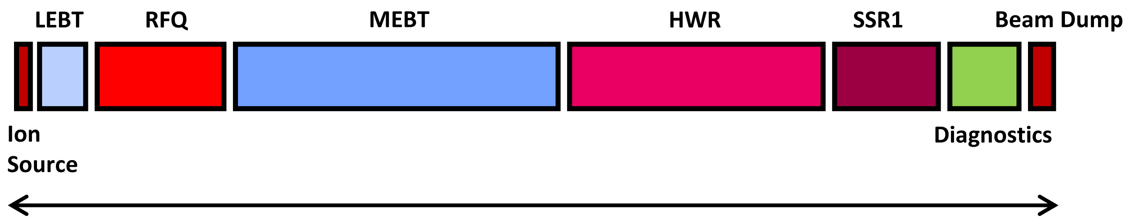

FIGURE 1: Major Subsystem in the PXIE Linac

2. Scope:

The RFQ design includes all of the beamline components necessary to accelerate and focus the beam from the exit of the LEBT to the entrance of the MEBT according to Project X front-end specifications. The design will also include all RF power sources, RF power distribution, RF power couplers, vacuum pumps, vacuum controllers, support stands, alignment fixtures, and cooling mechanisms required for reliable operation.

The RFQ will operate with continuous wave RF power and support peak currents of 5mA. A future upgrade path for Project X envisions operations with RFQ beam current as high as 10 mA, so this should be planned for to the extent possible.

3. Key Assumptions &Interfaces:

The RFQ will conform to FNAL Engineering[5] and ES&H Standards.[6] The design must be coordinated with the following PXIE design interfaces:

- LEBT beam properties, alignment, and vacuum load
- MEBT beam properties, alignment, and vacuum load
- Facility layout
- RF control and protection
- General communications, controls and diagnostics
- Water distribution system

- AC Power
- Personnel and machine protection systems

4. Requirements & Constraints

Table 1. RFQ Requirements & Constraints

Physical		
	Beamline height from the floor	1.3 m
	Overall width	≤1.6 m
	Overall length (flange-to-flange)	≤4.55 m
	Overall height (from floor)	≤2.00 m
Beam		
	Ion type	H-
	Input beam parameters	Match to LEBT at 5 mA
	Nominal Input energy (kinetic)	30 (+/- 0.5%) keV
	Nominal output energy (kinetic)	2.1 (+/- 1%) MeV
	Nominal Beam Current	5 mA
	Beam Current Operating Range	1- 10 mA
	Transmission efficiency (1-10 mA)	95%
	Transverse emittance (normalized, rms) over 1-10 mA Operating Current Range	< 0.25 mm mrad
	Longitudinal emittance (rms): over 1-10 mA Operating Current Range	0.8 – 1.0 eV-µs
	Output beam parameters at 5 mA beam current	$\lvert\alpha_x\rvert< 0.2$
		$\lvert\alpha_y\rvert< 0.2$
		$\lvert\alpha_z\rvert< 0.1$
Alignment		
	Max transverse position error (X,Y) at upstream and downstream beam flange	0.1 mm
	Max longitudinal position error (Z)	2 mm
RF		
	Frequency	162.5 MHz
	Duty factor (CW)	100%
	Total RF power for resistive losses and beam loading	<130 kW
	Peak RFQ copper temperature at full power	~50 C
	Nominal cooling water temperature	30 C
Vacuum		
	Operating pressure	< 5x10^{-7} torr

* The rms emittance is defined using the moments of the particle distribution in phase space (e.g. $x-x'$) as follows: $\varepsilon_x = \left(\overline{x^2}\,\overline{x'^2} - \overline{xx'}^2\right)^{1/2}$. In modeling, it is based on 100% of particles; in experiments, it may be based on a truncated number of particles (95-100%) to reduce the effect of far tails on the calculated emittance value.

[&] To express the longitudinal rms emittance in mm-mrad, multiply it by $(M_p c)^{-1}$, 0.32 mm-mrad/(μs-eV) for protons and H^- ions.

5. References:

Documents with reference numbers listed are in the Project X DocDB:
http://projectx-docdb.fnal.gov

[1] Project X Functional Requirements Specification
Document #: Project-X-doc-658

[2] Project X Injector Experiment Functional Requirements Specification
Document #: Project-X-doc-980

[3] PXIE LEBT Functional Requirements Specification
Document #: Project-X-doc-912

[4] PXIE MEBT Functional Requirements Specification
Document #: Project-X-doc-938

[5] Fermilab Engineering Manual
http://www.fnal.gov/directorate/documents/FNAL_Engineering_Manual_REVISED_070810.pdf

[6] Fermilab ES&H Manual
http://www-esh.fnal.gov/pls/default/esh_home_page.page?this_page=15053